Cyclonic Flotation Column for Minerals Beneficiation

Ralph W. Lai

ABSTRACT

This paper describes the application of a cyclonic flotation column (CFC) for coal cleaning. A CFC makes use of centrifugal force to create a density gradient in a column to augment the froth flotation process. In a CFC, a series of angular helical inserts is attached to the wall of a conventional column and coal slurry is mixed with a series of impellers attached to a central shaft. The hydrophobic froth concentrates near the center shaft and moves upward, while the relatively heavy hydrophilic particles concentrate near the wall and are guided downward by the helical inserts. Results of pyritic sulfur removal from an Upper Freeport coal during CFC flotation are discussed in this paper.

INTRODUCTION

This paper introduces a cyclonic flotation column (CFC) for special application in coal and mineral separation. In a CFC, the separation of materials is based on the dual effects of froth flotation and gravity separation. Froth flotation is a surface-based separation process where the separation of particles is based on the difference in the surface hydrophobicity of the materials. Gravity separation is a physical process where the separation of particles is based on the density difference of the materials. A combination of froth flotation and gravity separation is useful in special applications in which neither process alone can effect an adequate separation.

One application of the CFC would be in coal cleaning, where it is desirable to separate pyrite (sp.g. 5.5) and ash-forming minerals (sp.g. 2.8) from coal (sp.g. 1.3). Due to its natural floatability, pyrite tends to float with coal during flotation. Thus, flotation is not effective in removing pyrite. However, if the froth flotation process is augmented with gravity separation, pyrite can be effectively separated from coal. In this paper, results are described for two series of batch CFC experiments using an Upper Freeport coal.

Another potential application for the CFC is in iron ore beneficiation. During the cationic flotation of silica from iron oxides, the froth tends to entrain a significant amount of fine iron oxides in the water phase of the froth. When the froth flotation process is augmented with gravity separation, iron oxides can be effectively removed from the water phase through the enhanced centrifugal force and thus iron recovery can be improved.

The Cyclonic Flotation Column

In a cyclonic flotation column (CFC), a series of angular helical inserts is attached to the wall of a conventional column to function as a pyrite particle retardant. During flotation, coal slurry is mixed with a series of impellers attached to a central shaft. A lightweight froth, rich in coal, is formed through the attachment of coal particles to the rising air bubbles. The froth, due to its relatively lightweight, should concentrate near the center of the shaft and move upward. The heavy pyrite, due to its high specific gravity, should swirl along the wall of the column, be caught by the angular helix, and be washed downward by the movement of water. This action of moving heavy materials downward is similar to a cyclonic operation. Schematic of the action of CFC column is shown in Figure 1. The experimental column has the dimension of 10.16 centimeters (4 inches) diameter and 1.82 meters (6 feet) height.

There are two potential advantages to using the CFC. (1) There is no need of water washing. (2) Froth forms a vortex and flows along the shaft upward, while the pyrite and clay minerals flow downward along the wall; thus, a traffic jam is avoided for the upward flow of froth and the downward movement of pyrite and mineral laden slurry phase.

EXPERIMENTS AND RESULTS

An Upper Freeport seam coal from Indiana county, Pennsylvania was used for flotation experiments using MIBC as frother. The coal contains 11.7% ash forming minerals, 2.27% pyritic sulfur and 13,600 BTU/lbs. The results of coal cleaning with a batch mode CFC at 1500-rpm mixing were compared with those of a batch mode open column without using wash-water and those of the Wemco cell. The coal was first conditioned with 0.5-kg/Mt kerosene then with 0.5-kg/Mt MIBC in a separate vessel, then charged into the column. Additional 0.5 kg/Mt of MIBC was added to the column before introducing the air into the column. Clean coal froth was collected in a kinetic fashion at the specified time and analyzed for pyritic sulfur and heating values. Table 1 gives the coal recovery and the analyses.

Figure 1 compares the pyritic sulfur content of the clean coal products as a function of combustible recovery for the CFC and open column using the 100M x 0 Upper Freeport coal. Figure 2 compares the pyritic sulfur content of the clean coal products as a function of combustible recovery for the CFC and Wemco cell using the 100M x 325M Upper Freeport coal. Both figures indicate that for a given combustible recovery, the pyritic sulfur content of the cleaned coal is relatively high for the open column and the Wemco cell - an indication that the pyrite tends to float with the coal. Figure 1 indicates that the CFC operation yielded clean coal containing much less pyritic sulfur than that of the open column. Figure 2 also indicates that the CFC operation yielded clean coal containing much less pyritic sulfur (less than 0.5% sulfur) than that of the Wemco cell (above 1% sulfur) for a wide range of combustible recoveries. It is clear that the pyritic sulfur rejection by the CFC is superior to that of the Wemco cell and open column. This superiority of pyrite rejection comes from the ability of the CFC to generate centrifugal force to separate the high-density pyrite.

CONCLUSION

A cyclonic flotation column is a froth flotation apparatus with an added advantage of density separation. Batch testing with an Upper Freeport coal, at 100M x 325M and 100M x 0 feed sizes, indicate that the apparatus is effective in cleaning pyrite from coal.

Figure 1 Schematic of the action of CFC column

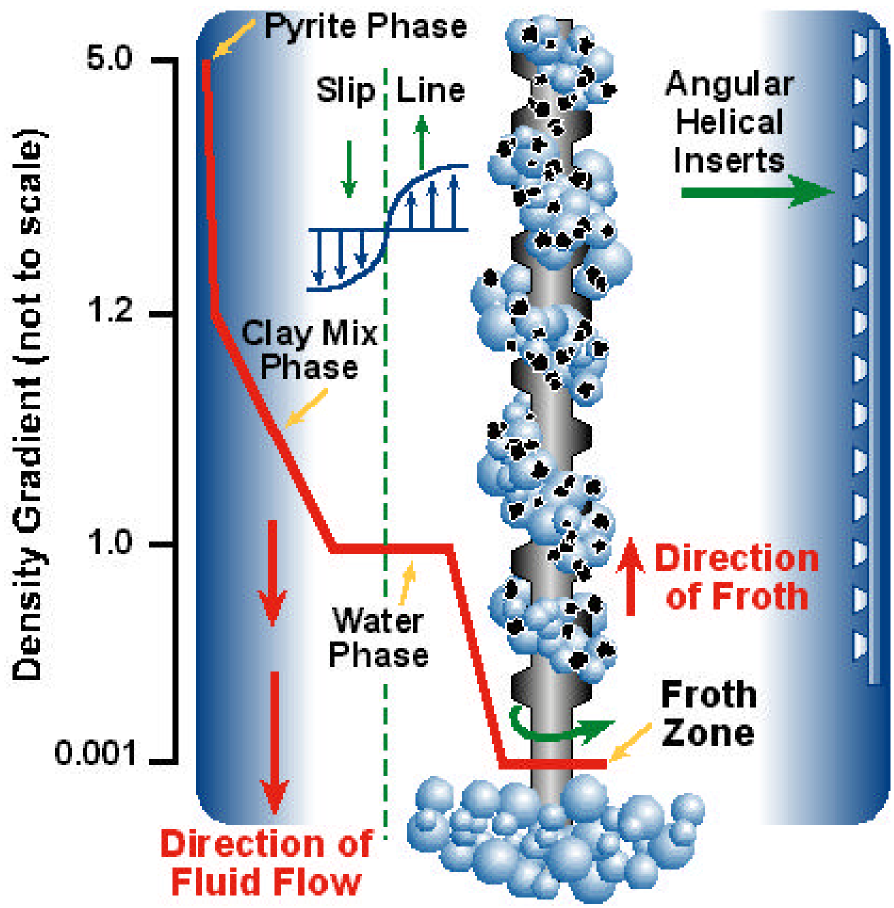

Fig. 2 Pyritic Sulfur Content in the Recovered Clean Coal Product
(100M x 0 Upper Freeport Coal)

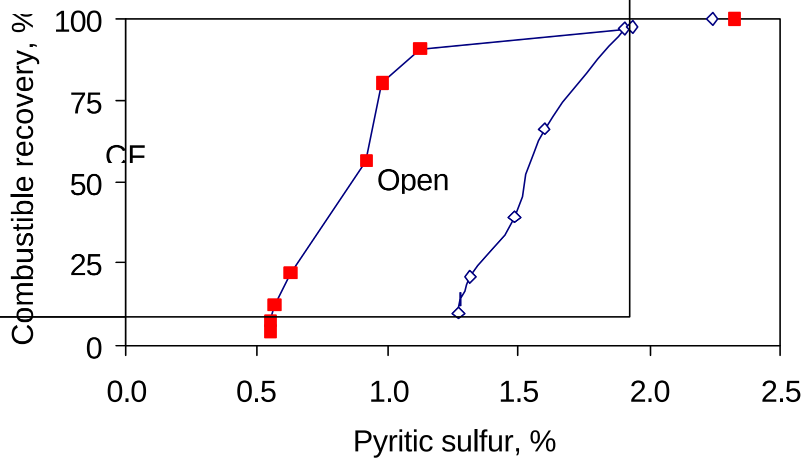

Fig. 3 Pyritic Sulfur Content in the Recovered Clean Coal Product
(100M x 325M Upper Freeport Coal)

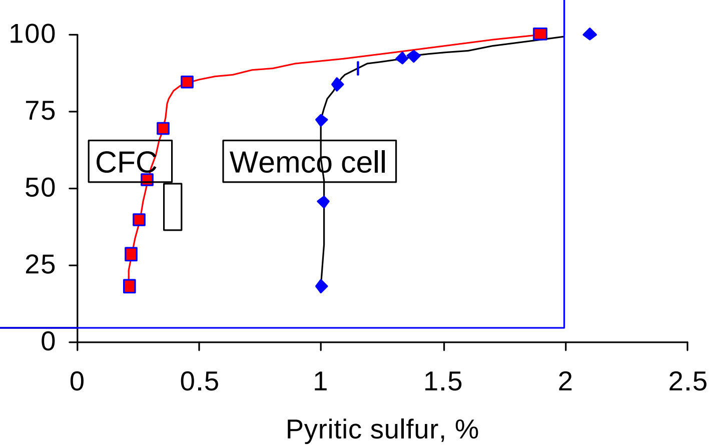

Table 1 Comparative flotation recovery of Upper Freeport coal (100M x 0)

column	Time, min.	Wt. %	Py S, %	Cum. % Py S	Btu	Cum. % Btu
open	0.5	9.32	1.27	1.27	14306	9.90
	1	4.17	1.30	1.28	13514	14.08
	2	6.48	1.40	1.31	14248	20.93
	4	17.3	1.68	1.49	14117	39.08
	8	26.3	1.75	1.59	14074	66.56
	16	30.1	2.56	1.90	13626	97.00
	24	0.85	4.79	1.93	11346	97.72
	Tails	5.41	7.59	2.23	5674	100.0
	Total	100				
CFC 1500 rpm	0.5	4.11	0.55	0.55	14896	4.48
	1	2.41	0.56	0.55	14878	7.11
	2	4.60	0.59	0.57	14966	12.16
	4	9.08	0.70	0.63	14877	22.07
	8	31.4	1.10	0.91	14852	56.26
	16	22.4	1.13	0.98	14564	80.21
	32	10.1	2.17	1.12	13982	90.52
	Tails	15.9	8.69	2.32	8122	100.0
	Total	100				